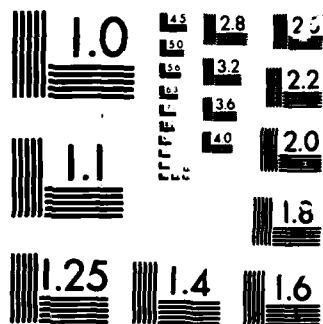


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HYPOBARIC CHAMBER(U) ARMY RESEARCH INST OF
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controlled by an incremental throttling valve in the vacuum line. Temperature (0-100°C) is accomplished by using a remote-controlled constant temperature circulating bath. RH (20-80%) is regulated by pre-conditioning the ventilation purge air prior to entering the chamber. Acceptable levels of oxygen and carbon dioxide gases are maintained by purging with sufficient volumes of fresh air.

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AN ENVIRONMENTALLY-CONTROLLED EXTENDED-USE
SMALL ANIMAL HYPOBARIC CHAMBER

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Running Head: Animal Hypobaric Chamber

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ABSTRACT

An environmentally-controlled extended-use small animal hypobaric chamber has been designed to study small laboratory animals at low barometric pressures for long periods of exposure. The rectangular chamber (91.4 x 71.1 x 50.8 cm) is constructed of aluminum plate and acrylic resin with a volume of 3.3×10^5 cm³. A computer/data acquisition control unit provides for controlling and collecting data on pressure, temperature, and relative humidity (RH) for sustained operations. Altitude simulation is achieved using a two-stage, air-cooled vacuum pump with a displacement of 30 cm³/min. The pressure within the chamber is controlled by an incremental throttling valve in the vacuum line. Temperature (0-100° C) is accomplished by using a remote-controlled constant temperature circulating bath. RH (20-80%) is regulated by pre-conditioning the ventilation purge air prior to entering the chamber. Acceptable levels of oxygen and carbon dioxide gases are maintained by purging with sufficient volumes of fresh air.

Index Terms: rodents; atmospheric pressure simulation; altitude; temperature; relative humidity



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In recent years, there has been a growing number of scientists interested in the adaptive mechanisms of experimental animals to conditions of environmental stress, particularly temperature and altitude. Despite considerable attention, research has been limited due to restricted access of facilities that simulate altitude. Many investigators have fabricated hypobaric chambers from existing laboratory hardware (1,2,3,4,5).

Hypobaric chambers used for human studies (man-related) and chambers designed to evaluate equipment performance at altitude could be adapted for animal research studies. Most are expensive to operate, lack the sophistication in control systems for long-term confinement studies, and are not readily available for the scientific community. The small animal hypobaric chamber was designed for construction in the laboratory or department machine shop. The control system can be assembled with off-the-shelf instrumentation and other equipment usually available in a research laboratory.

SPECIFICATIONS

The chamber is a rectangular shaped vessel, primarily constructed of aluminum plate and cast acrylic resin (Fig. 1) measuring 91.4 x 71.1 x 50.8 cm with an internal volume of $3.3 \times 10^5 \text{ cm}^3$. The skeletal structure is a framework of aluminum angle 0.6 x 5 x 5 cm that is designed to support loads imposed by the differential pressure. The end caps and base are cut from 0.6 cm aluminum plate and reinforced with transversed structures (stiffeners) that divide the unsupported areas into smaller configurations for maintaining the metal

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integrity when under large differential pressure stresses. Electrical penetrations utilize air-tight fittings and are fed through the aluminum end caps. The sides and top are 2.5 cm acrylic resin providing maximal visual surveillance of inside activities. Access to the chamber interior for experimental set-up and cleaning is provided by a removable top. Quick release cam-lock type clamps are used for securing the top to the chamber. Clamps are strategically placed to apply an even distribution of compression on the rubber gasket to facilitate the initial vacuum application. A plenum housing, containing a heat exchange coil, is welded externally to the aluminum end cap of the chamber. Located within the plenum is a miniature air circulating fan and a molded air channeling baffle plate for smoothing and concentrating air flow through the coil (Fig. 2).

CONTROL SYSTEMS

Altitude Simulation: Chamber pressure is automatically controlled using a computer (Hewlett Packard 200S-16) and a data acquisition/control unit (DACU, Hewlett Packard 3497A). The DACU digitizes an analog voltage derived from a digital pressure gauge (Mensor 8240). The computer then uses the digitized signal in a feedback loop software program to control an incremental Solenoid valve on a thermal mass flowmeter (Porter F-2-2MFC). A vacuum pump (Gast 1022) is used to reduce pressure in the chamber compartment.

Ventilation Air: Acceptable levels of oxygen and carbon dioxide gases are maintained by purging the chamber with sufficient volumes of fresh air. Incorporated in the software program are additional feedback signals in which chamber oxygen and carbon dioxide concentrations are compared to reference values and appropriate adjustments made by a second mass flow controller to the

purge ventilation line. Medical gas analyzers (Beckman OM-14, oxygen; LB-2, carbon dioxide) are used to measure gas concentrations. Measurements are obtained by drawing air samples from vacuum exhaust line.

Temperature Control System: Temperature control ($0-100^{\circ}\text{C}$) is effected by using a remote-controlled circulating bath (Lauda KTC-4). Constant temperature control capabilities are provided by built-in mechanical refrigeration and heating units. A remote thermistor is mounted inside the chamber allowing the interior to be the control point. Fluid (glycol/water) is circulated through the chamber's heat exchange coil (Eastern Industries E/HT 200) and returned to the circulating bath. Concurrently, air is circulated around the fins of the coil transferring fluid temperature into the chamber interior. A ceramic enclosed platinum resistance sensor element is used to measure the temperature. The sensor is housed in an environmentally-rated anodized aluminum collar (pressure boss) designed for pressure/vacuum applications. The pressure boss enables the sensor to be installed in the vacuum pump exhaust line, where air being drawn from the chamber circulates around the sensor providing the measurement. Temperature and relative humidity data are displayed on a digital readout instrument (General Eastern 400E) with analog output for recording (Fig. 3).

Relative Humidity Control System: Relative humidity (RH) is controlled by employing the chambers ventilation air systems (0-20 liters per minute, L/min) as a means for injecting pre-conditioned air. Humidification is accomplished by passing ventilation air through a water jacketed-aerator. The amount of saturation is controlled by modulating an ambient air bypass line to mix with the humidified line until desired set-points are reached. Dehumidification is

accomplished by passing ventilation air through a condenser (Allihn C7930) where moisture collects on the inner surface of the cooled tube with water droplets collecting in a condensate container below. The condenser is cooled using an instrument (Vortex 208) that converts ordinary compressed air (1137 kg/cm^2) into a cold stream of air (-40°C). The amount of water being removed from the ventilation air stream is proportional to temperature of cold air supplied to the condenser from the vortex tube. Humidity is measured using sulfonated polystyrene resistance (AC) grid housed in the pressure boss.

DISCUSSION

Chamber Design: The hypobaric chamber combines a computer with a data acquisition control unit for monitoring, controlling, and collecting data with a design goal for simulating conditions found at high terrestrial elevations. The chamber's pressure, temperature, and relative humidity are controlled and monitored. Ventilation air purges animal metabolic gases to maintain normal partial pressures of oxygen and carbon dioxide. Concurrently, air is circulated by a variable speed boxer fan through the heat exchanger and returns to the chamber proper creating a thoroughly mixed homogeneous environment. Portability was considered in the structural design. Materials (acrylic resin and aluminum) were chosen on the basis of high strength to weight ratios. Additionally, acrylic resin permits maximal surveillance of inside activities and a natural insulation for cold environment simulations. The chamber's rectangular shape allows for housing a number of animals or cages simultaneously.

ACKNOWLEDGEMENTS

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The views, opinions, and/or findings contained in this report are those of the authors and should not be construed as an official Department of the Army position, policy, or decision, unless so designated by other official documentation. All animal research conducted by the investigators adhered to the "Guide for the Care and Use of Laboratory Animals" as prepared by the Committee on Care and Use of Laboratory Animals of the Institute of Laboratory Animal Resources, National Research Council.

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LEGENDS

Fig. 1. Specific views of assembly along with dimensional and engineering data.

Fig. 2. Exploded view of the hypobaric chamber showing individual sections and indicates their proper relationship to the unit when assembled. Also included are dimensional data for the heating/cooling coil.

Fig. 3. Schematic showing the computerized data acquisition and control instrumentation used to create the environmental simulation of the hypobaric chamber.

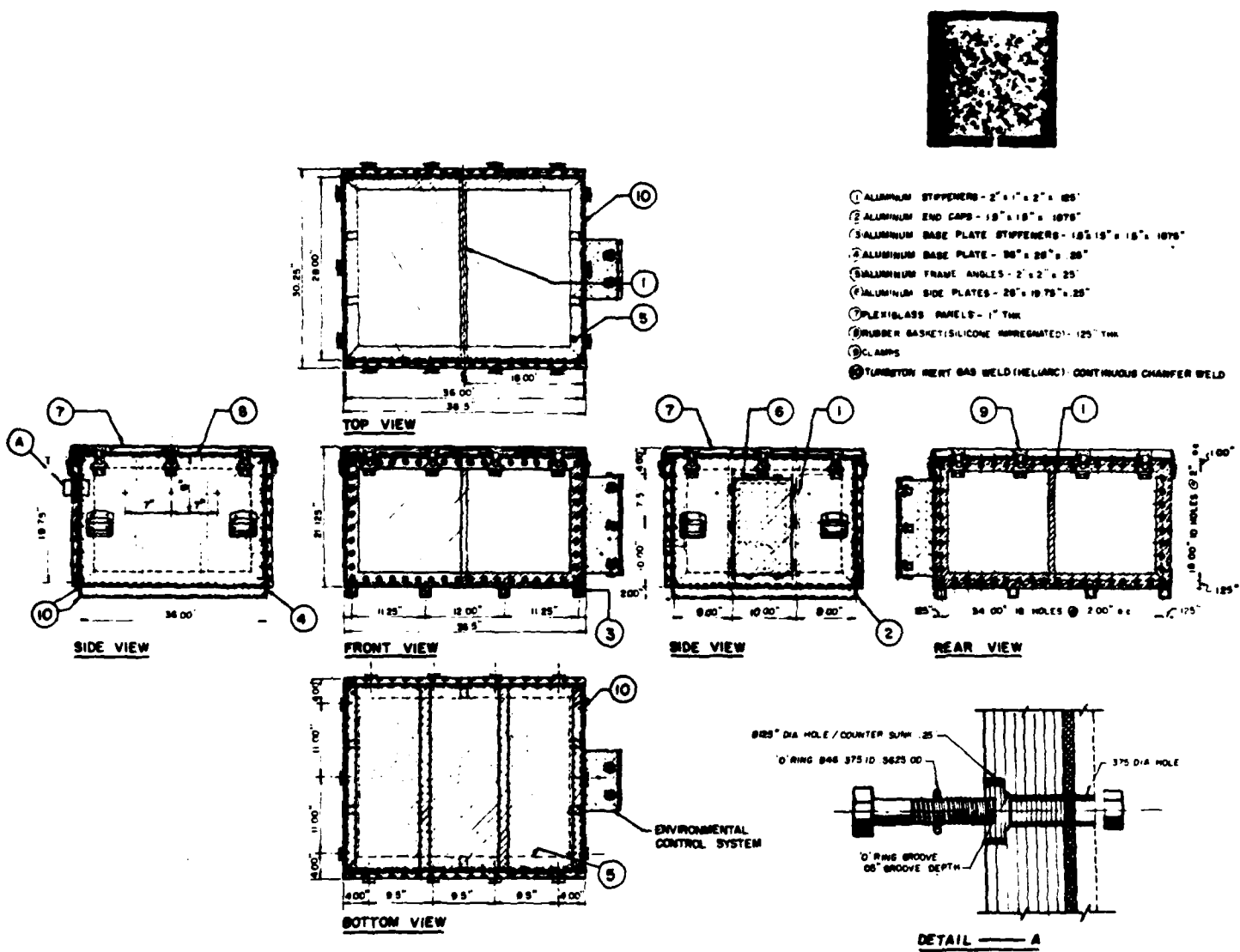
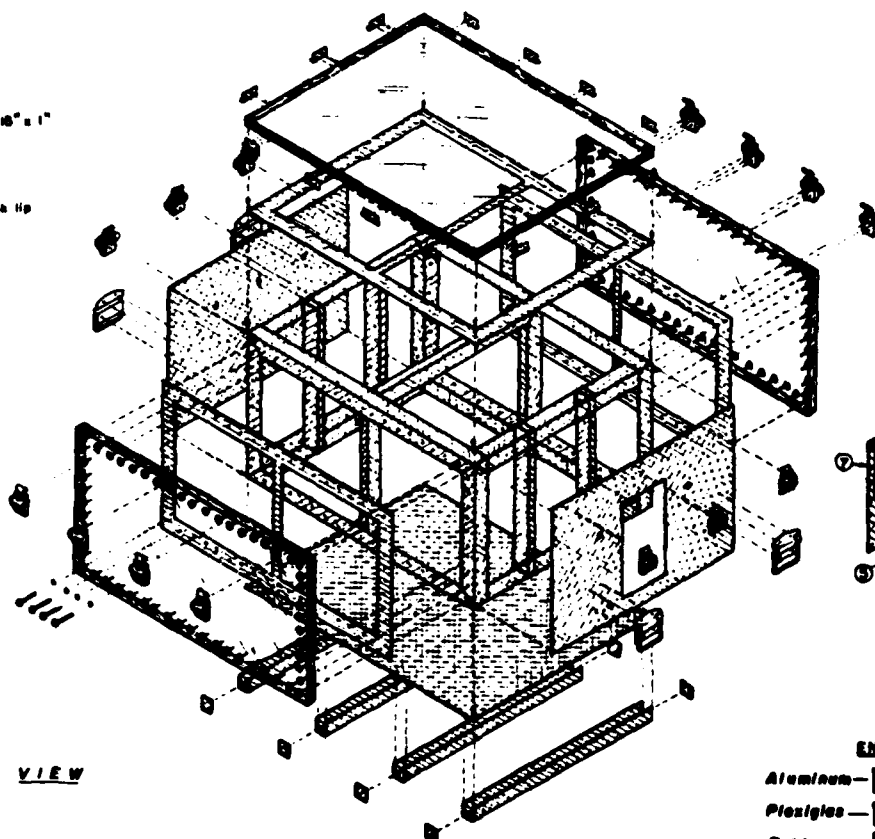


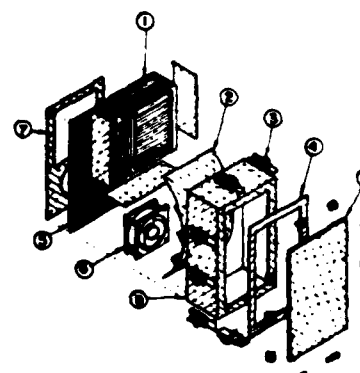
Fig. 1.

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- ① HEATING / COOLING COIL
- ② BAFFLE w/ VAINS
- ③ ALUMINUM CLAMPS
- ④ RUBBER GASKET .125" x 9" x 15" x 1"
- ⑤ SCREEN
- ⑥ FAN
- ⑦ SCREEN COVER
- ⑧ HOUSING .25" x 9" x 15" w/ .5" Wb Hp
- ⑨ COVER 25" x 9" x 15"



EXPLODED VIEW



ENVIRONMENTAL CONTROL SYSTEM




Aluminum — 
 Plexiglas — 
 Rubber — 

Fig. 2.

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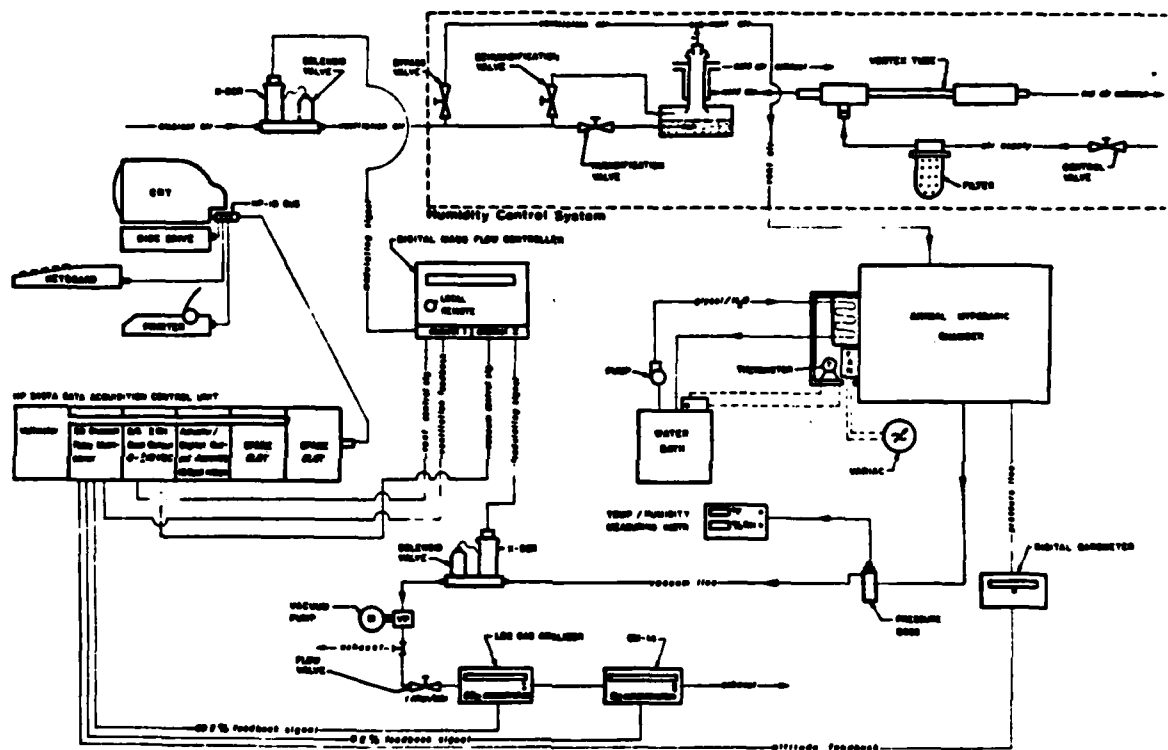


Fig 3.

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